

## The mystery of T Pyx; the 2011 explosion

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**Abstract.** T Pyx is a recurrent nova which has undergone eruptions on an almost regular basis every 20 years until reaching a long lasting quiescence between 1967 and 2011. We observed the long awaited 2011 explosion in the optical and near infrared with intermediate spectral resolution. In this paper we report on the change in the spectral type of the nova (both during its rise and during its fading), as well as the observed changes in the expansion velocities. We also present an interpretation of these changes and set them in the general framework of a new understanding of nova classification

### 1. Introduction

Recurrent novae (RNe) are a subclass of novae whose characteristics is to have more than one observed explosion. This means that the recurrence time ( $\tau_R$ ) is smaller than the  $10^4$  years which is expected for classical novae. Such short  $\tau_R$  is explained assuming a massive white dwarf (approaching the Chandrasekhar mass) which would need to accrete less mass in order to ignite thermonuclear reactions on its surface.

So far, about a dozen recurrent novae are known and they are divided in different classes: the TCrB/RS Oph class, the USco class and the TPyx class, based on the eruption properties (see Starrfield 2008 and Anupama 2008).

The “TPyx” class is made of objects which look more like “normal” classical novae than like RNe. These objects have comparatively short periods (below the “period gap”) and are classified as “slow novae”. Actually, only IM Nor and TPyx itself fall in this class.

TPyx was first observed in eruption in 1890 and, since then, it has had semi-regular eruptions (see Fig.1). The eruption predicted for the end of the 1980s has never been observed thus giving rise to a series of speculations on the nature of this object as well as on its next eruption (see, e.g., Schaefer et al. 2010 and Selvelli et al. 2008 and references therein). It was only recently (Uthas 2010), that the period of the binary was finally measured: 1.8295 h. Making assumptions on the type of the secondary star, Uthas (2010) also derived a mass for the white dwarf of  $0.7 \pm 0.2 M_\odot$ . which is much less than expected for a RN.

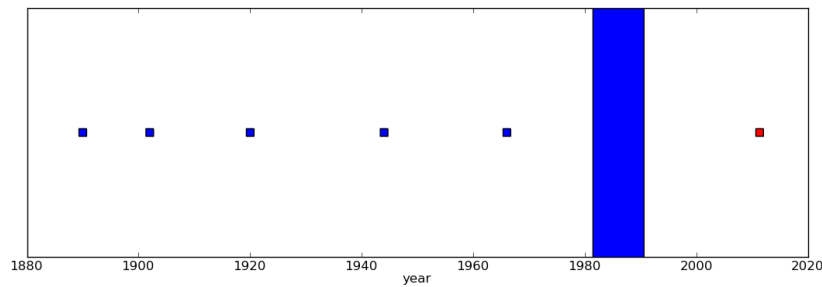


Figure 1. Historical eruptions of T Pyx. The shaded area is obtained by summing to the epoch of the last eruption the average (plus or minus the standard deviation) of the till-then recurrence times.

## 2. The 2011 Eruption

### 2.1. The light curve

The long-awaited eruption of T Pyx occurred on Apr 14, 2011. It was reported by Waagan et al (2011). Within 2 days the nova brightened by 7 mag. This phase was followed by a “plateau”. On day 8, the light curve shows a last rise to maximum light ( $V \sim 6.5$  mag) which occurred on day 28.5. The colors show some interesting evolution (see lower panel of Fig.2). The  $B - V$  increases steadily from day 0 to day 20 and then start decreasing (although with some oscillation). The  $V - R$  increases only during the first 5 days and then stays (almost) constant throughout the evolution. Apparently, only after day 80 the  $V - R$  clearly departs from this almost constant value. It is interesting to observe a bump which is present both in the B-band plot and in the color plots around day 45. It may look like an episode of dust formation but it has been observed (Evans et al. 2012) that T Pyx has not formed dust (at least, not during this eruption).

It is interesting to make a comparison between the 1966 and the 2011 eruption. Fig.2 shows, in the upper panel, the visual band light curve of the 1966 eruption and the B-band light curve of the 2011 eruption. For clarity, both light curves have been re-sampled to a 1 day. Although the light curves are not identical (and taking into account the difference in bandpass), the light curves are remarkably similar, both showing the same steep rise (although the 1966 light curve does not seem to show the same pre-maximum plateau as the 2011 one) and the same slow decline. The time between the 2011 eruption and its predecessor almost doubles the time between the 1966 and its predecessor (see, again, Fig.1). It is therefore quite remarkable that these two events show the same photometric characteristics, unless one assumes that the mass transfer rate is reduced by a factor of almost two before and after the 1966 eruption.

### 2.2. The spectrum

The present spectra obtained with the X-Shooter spectrograph on the Very Large Telescope between the day after the eruption and when the star was too close to the Sun to be observed. X-Shooter is a multi-arm cross-dispersed echelle spectrograph. Two dichroics split the light in the three arms: UVB, VIS and NIR, covering roughly 3000-5500Å, 5500-10000Å, and 10000-24000Å, respectively. A montage of the UVB spectra is shown in Fig.3. The first spectrum that we present here was obtained on Apr 15, 2011,

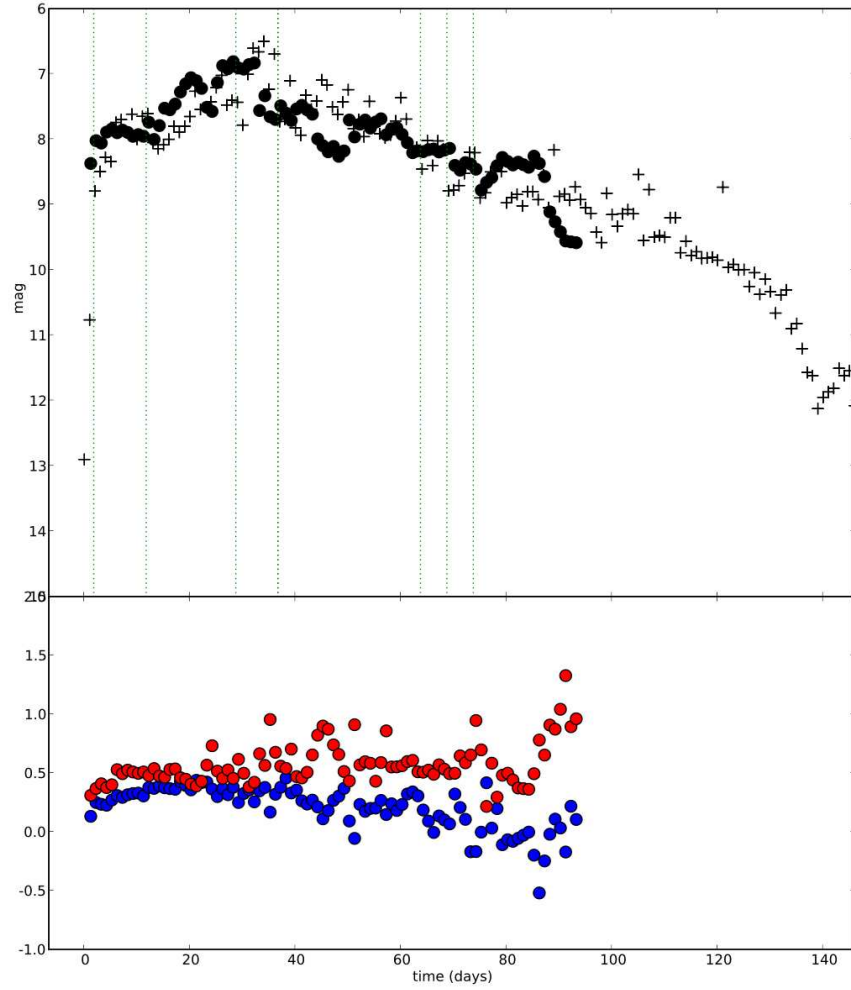


Figure 2. AAVSO photometry of the 1966 and the 2011 eruptions of T Pyx. *Upper panel:* Crosses show the visual light curve of the 1966 eruption while black dots show the B-band light curve of the 2011 eruption (time is in days since discovery). *Lower panel:* Red points show the V-R color of the 2011 eruption while blue points show the B-V in the same eruption.

about 26 hours after the report of the explosion. The spectrum shows Balmer lines with P-Cyg profiles with expansion velocities of about  $1300 \pm 100 \text{ km s}^{-1}$  and FWHM of  $1130 \pm 200 \text{ km s}^{-1}$ . For a comparison, on the day of discovery Izzo et al. (2011), based on high resolution ( $R = \frac{\lambda}{\delta\lambda} \sim 57000$ ) spectra obtained with SARG on the Telescopio Nazionale Galileo (TNG), reported also P-Cyg profiles with expansion velocities of  $\sim 1800 \text{ km/s}$  and FWHM  $\sim 1200 \text{ km/s}$ . This is consistent with what is expected for an “Fe II” nova in the classification scheme by Williams (1992). Nevertheless, this spectrum shows no Fe II lines but clear He/N lines. It therefore falls in the “He/N” case as described by Williams (1992).

The second spectrum of our series was obtained 10 days after the eruption. The velocities (derived both through P-Cyg profiles and through FWHM) are reduced by almost a factor of two. The appearance of the spectrum is now completely different. The He and N lines are not detected and Fe II lines are clearly visible instead, thus making this spectrum a typical “Fe II” spectrum.

TPyx reached its maximum brightness on day 28.5 (see previous section). The spectrum at this stage (on May 12) shows Balmer lines, as well as Fe II lines and O I lines ( $\lambda 7773\text{\AA}$  and  $\lambda 8446\text{\AA}$ ). This is the typical spectrum of an “Fe II” nova at maximum light. Chesneau et al. (2011), based on near infrared interferometric data, has observed that, at this epoch, the expansion is bipolar. This does not show up in our spectra where the P-Cyg profile clearly only shows a single absorption. The expansion velocity, as measured from the FWHM, has started to increase again (the minimum being reached at the previous epoch).

The spectra between day 10 and day 60 do not differ much from the evolution of an Fe II nova. The P-Cyg profiles of the spectrum taken on May 20 show multiple structures. This has already been observed in other novae (e.g. V5114 Sgr, see Ederoclite et al. 2006). The spectrum taken on Jun 21, 2011 (day 65) shows the emergence of the [N II] line, thus suggesting the beginning of the nebular stage. Interestingly enough no other forbidden line is observed. It is relevant to observe, instead, that the Fe II lines are not visible (as expected in the evolution of an Fe II nova evolving to the nebular stage) but several He I and N II lines are observable, hence, suggesting that TPyx has evolved back in an “He/N state”. This transition “backwards” has already been reported for other novae (e.g. LMC 1988#2, see Williams 1992), yet it is unusual the simultaneous presence of He I, N II, [N II] while the Balmer lines are still produced in a relatively dense wind (as shown by the P-Cyg profiles).

### 3. Summary and Conclusions

The RN TPyx was observed to begin its sixth known eruption on Apr 14, 2011. This reached maximum light on May 13, 2011 at  $V \sim 6.5 \text{ mag}$  and a  $t_2 \sim 20 \text{ days}$ . The photometric evolution looks qualitatively comparable with the one of the 1966 eruption, thus implying that similar physical processes must be at work. Assuming that the mass accreted for the ignition is roughly the same (i.e. the white dwarf does not change significantly its mass during an explosion), this implies that the mass accretion rate must be decreasing. A similar conclusion has been drawn by Schaefer (2005).

The spectroscopic evolution is highly unusual (as already mentioned in Williams 2012). The nova evolves from a “He/N” phase to an “Fe II” phase and then back to the “He/N” phase. We suggest the naming “hyper-hybrid” for this type of behavior and suggest that it is due to a change in the optical depth in the ejecta. We speculate that the

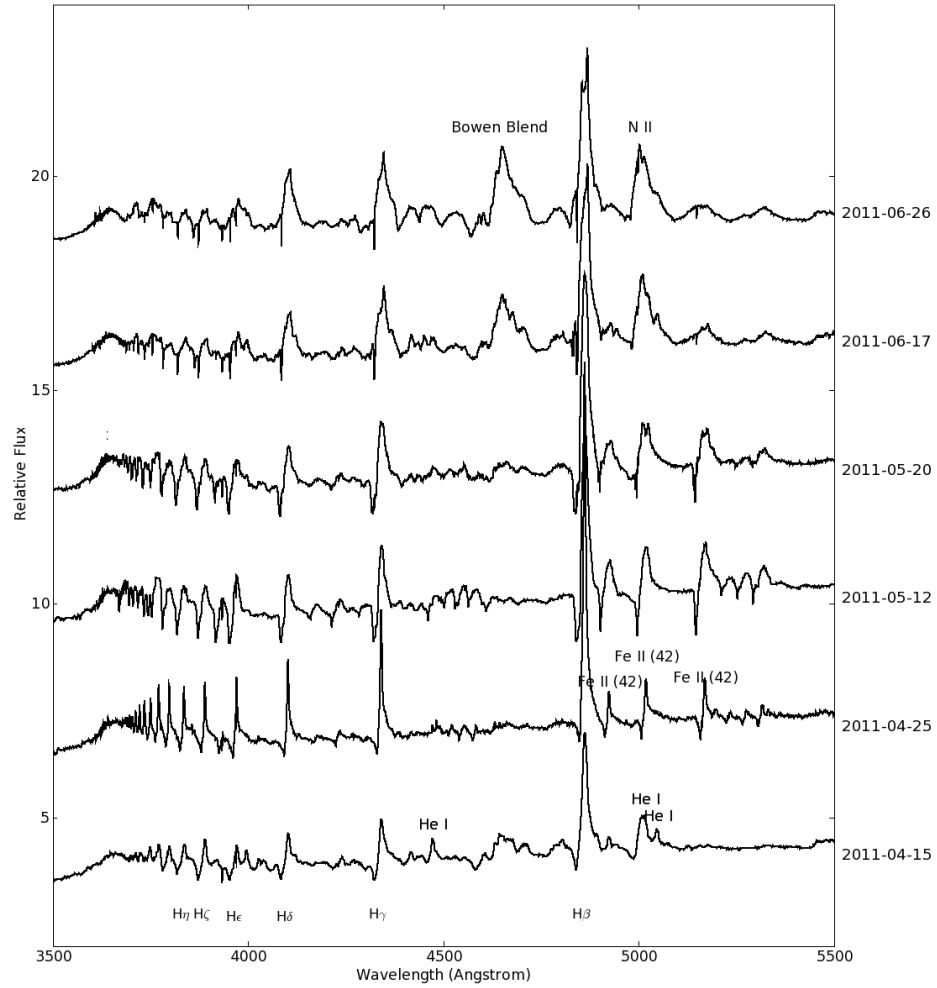


Figure 3. Montage of the X-Shooter spectra obtained in the framework of the present project. In order to be plotted in the same figure, the spectra have been divided by their average value and then an arbitrary offset has been added. Time goes from bottom to top. For clarity, only the UVB arms is shown. The rest of the spectra will be shown in a forthcoming paper.

first spectral type change may be common in novae but it is normally missed because of the short time it takes them to rise to maximum light. The second change may actually be due to a large physical extension of the ejecta in the radial direction. The furthest part of the ejecta has already low enough density that can emit forbidden lines whereas the inner part of the ejecta is still optically thick as witnessed by the P-Cyg profiles.

It should be mentioned that the minimum of the evolution of the expansion velocity is reached when the nova makes its first spectral type “transition” (hence suggesting that this is due to an inwards movement of the photosphere). Finally, the mentioned “bump” in the light curve (and in the color curves) between days 40 and 50 is right before the epoch when the “delayed mass ejection” invoked by Nelson et al. (2012) should occur and it is right before the “second spectral type change”.

Throughout this conference, T Pyx has shown to be always the exception to the rule. It is hard to tell if the evolution of T Pyx is unique or if its slow evolution has allowed us to probe phases which are otherwise common to all novae (or, at least, to a type of nova). High cadence observations (at high spectral resolution) would be required in order to tell the difference between T Pyx and other novae. Most importantly, T Pyx has evidenced our lack of understanding of the very early phase (the rise to maximum) where very unusual and unexpected changes have been observed, thus (again) showing the importance of fast response in the spectroscopic follow-up of this type of object.

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## References

- Anupama, G.C. 2008, ASPC, 401, 31
- Chesneau, O. et al. 2011, A&A, 534L, 11
- Ederoclite, A. et al. 2006, A&A, 459, 875
- Evans, N. et al. 2012, MNRAS, 424L, 69
- Izzo et al. 2011, IAUC, 9205, 3
- Nelson et al. 2012, submitted to ApJ
- Schaefer, B. E. 2005 ApJ, 621, L53
- Schaefer, B. E., Pagnotta, A. & Shara, M. M. 2010, ApJ, 708, 381
- Selvelli, P. et al. 2008, A&A, 492, 787
- Starrfield, S. 2008, ASPC, 401, 4
- Uthas, H., Knigge, C. and Steegs, D. 2010, MNRAS, 409, 237
- Waagan, E. Linnolt, M, Pearce, A. 2011, IAUC, 9205, 1
- Williams, R. E. 1992, AJ, 104, 725
- Williams, R. E. 2012, AJ, 144, 98